



# Accelerator R&D in Australia and Capabilities for the EIC

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Science. Ingenuity. Sustainability.

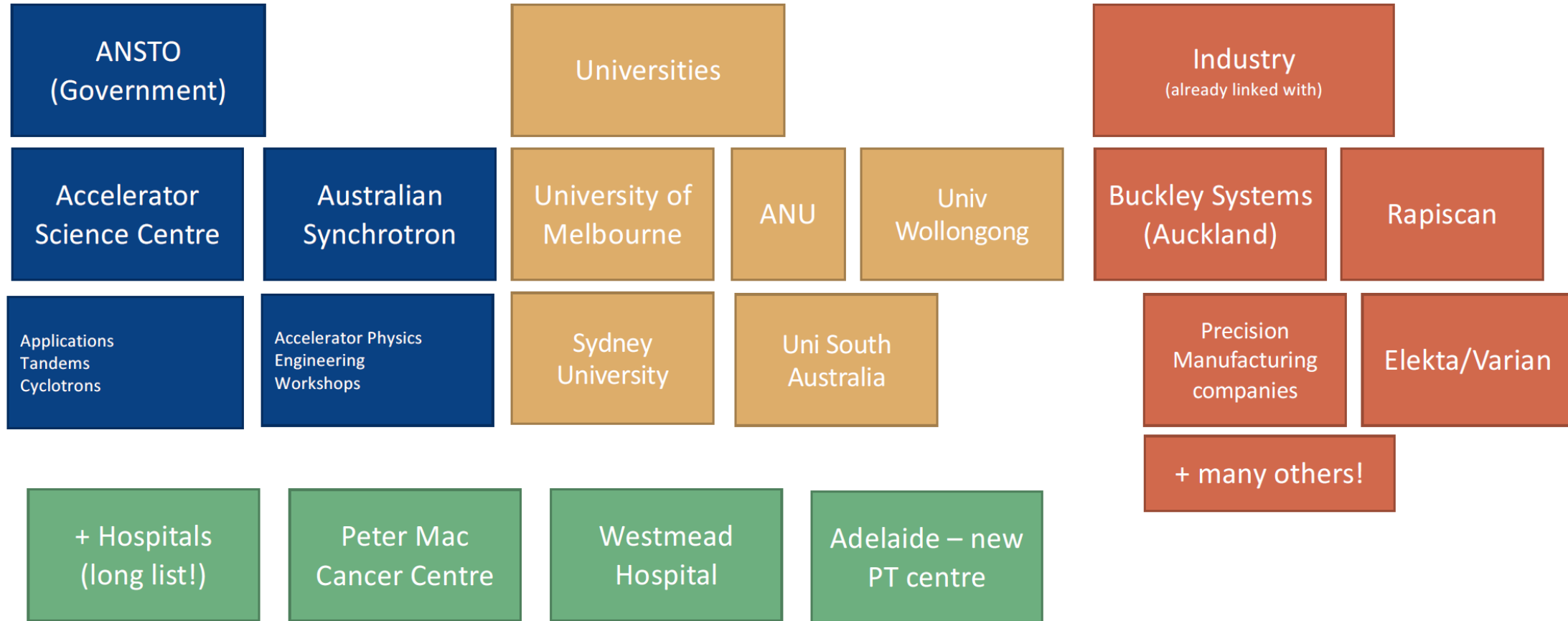
# Outline

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- Overview the accelerator community in Australia
- Current Accelerator R&D programmes in Australia
- Our capabilities and potential involvement

# Australian Accelerator Community

# The Accelerator Community in Australia (+NZ)



- As the major holder of large accelerator infrastructure in Australia ANSTO is the natural organisation to hold a major coordinating role in accelerator R&D. ANSTO is hosting a workshop at the end of this month to bring together all of these communities.

# Main Accelerator Facilities at ANSTO

- Australian Synchrotron Light Source (AS)
  - 3 GeV 3<sup>rd</sup> Generation Light Source in Clayton, Melbourne.
  - Electron storage ring, DBA lattice, 10 nm Hor. Emittance. 9+ Beamlines
- Centre for Accelerator Science (CAS)
  - A suite of 1-10 MV Ion accelerators at Lucas Heights, Sydney, for use in Ion Beam Analysis and Atomic Mass spectrometry
- Medical Accelerators
  - National Research Cyclotron Facility in Camperdown, Sydney. 18 MeV cyclotron for medical imaging radioisotope production
  - Involved in proton therapy facilities currently being built in Australia and backing development of an ion therapy centre in Sydney.

# Proton & Heavy Ion Accelerators in Australia

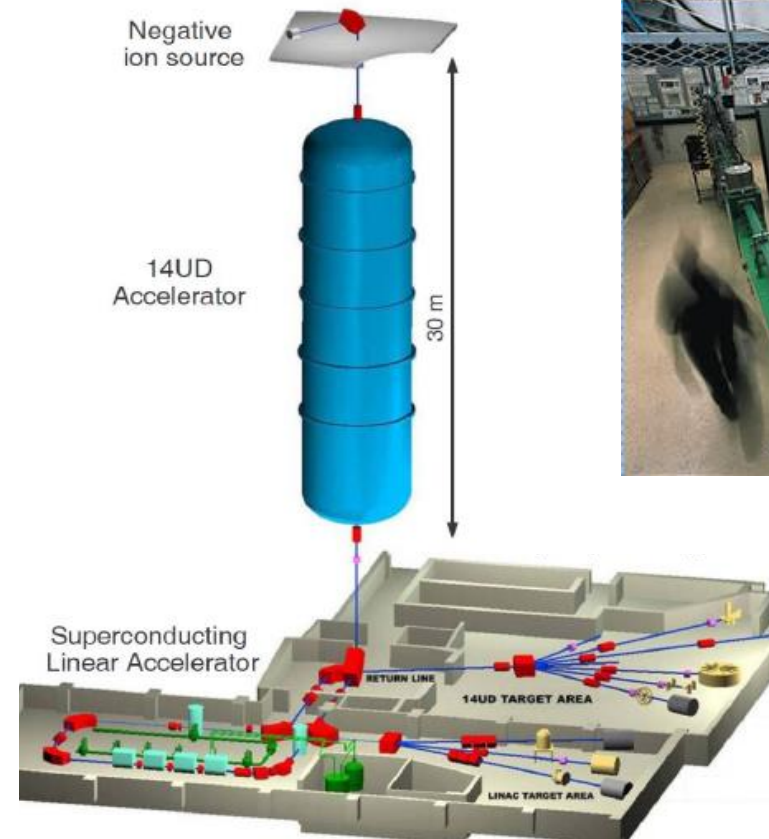


Centre for Accelerator Science, ANSTO  
4 Heavy ion accelerators: 1, 2, 6, 10 MV

Cyclotrons – PET  
Isotope production  
and Research.  
Pictured:  
ANSTO/NIF 18MV  
Cyclotron



ANU Heavy Ion Facility  
14 MV Tandem



Melbourne University 5MV  
Pelletron Accelerator



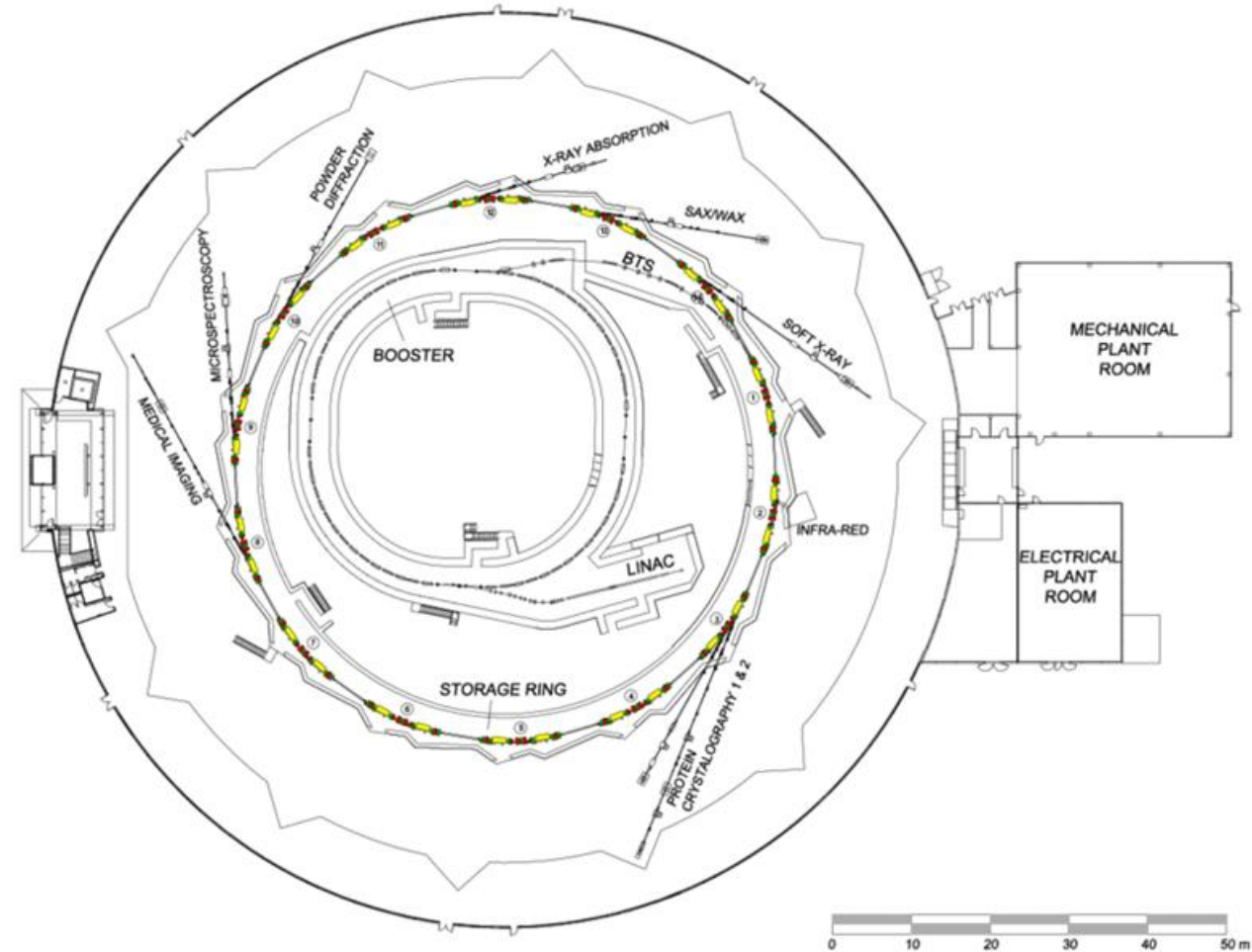
# Electron Accelerators

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- Low energy Linacs used in industry and used for irradiation and X-ray production for imaging, and therapy.
- These machines are commercially purchased from overseas. No complete accelerator manufacturing capability exists in Australia yet.
- High energy electron accelerators are concentrated at the Australian synchrotron.

# Australian Synchrotron

- 100 MeV linac
  - Delivered by RI (Accel)
- 0.1-3 GeV booster synchrotron
  - Delivered by Danfysik
- 3 GeV storage ring (216m)
  - 3<sup>rd</sup> Generation Light Source DBA lattice, 10 nm Hor. Emittance. 9+8 Beamlines
  - Magnets by Buckley Systems





# Accelerator Physics R&D in Australia



## Melbourne University Medical Accelerator Physics Group

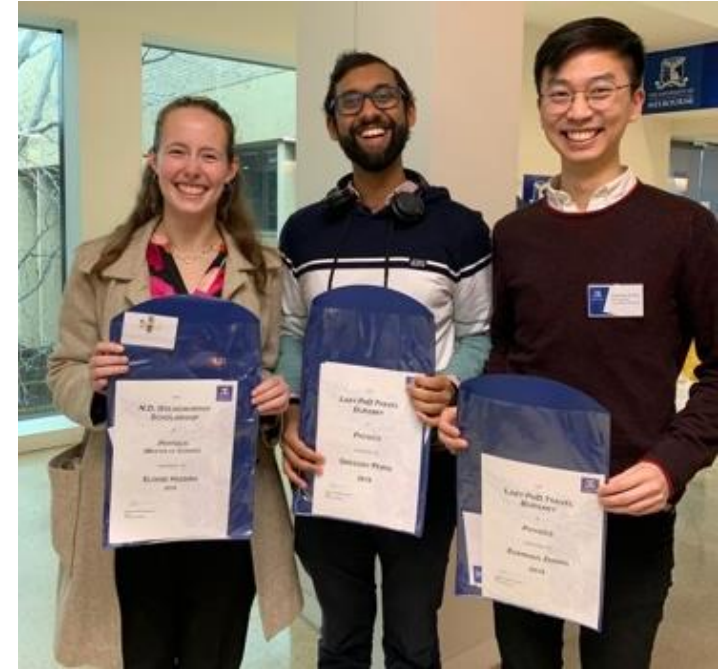
*“Our vision is to undertake world-leading research in accelerator physics in order to create positive societal impact – in Australia and globally. We will achieve this by creating a **physics through to experimental demonstration pathway** to take concepts from simulation to reality.” - Dr. Suzie Sheehy*

Key aspects of the groups approach:

- International collaborations
- Multi-disciplinary research
- Experimental and computational focus
- Industrial connection

The group is involved in:

- Collaborating in NIMMS for next-generation ion therapy machines (See F. Zhang)
- Development of novel gantry systems which are smaller, cheaper & more flexible using novel accelerator physics ideas
- 2 new joint PhD students (A. Steinberg, H. Norman) with Manchester University - involved in novel superconducting and/or FFA hadron therapy designs



**Jacinta Yap (PDRA) - started October 2020**

**Frank (Xuanhao) Zhang (PhD student):**

Next-generation hadron therapy accelerators and beam delivery systems.

**Greg Peiris (PhD student):**

Robust radiotherapy systems for challenging environments

**Adam Steinberg (start Oct 2020 Manchester)**

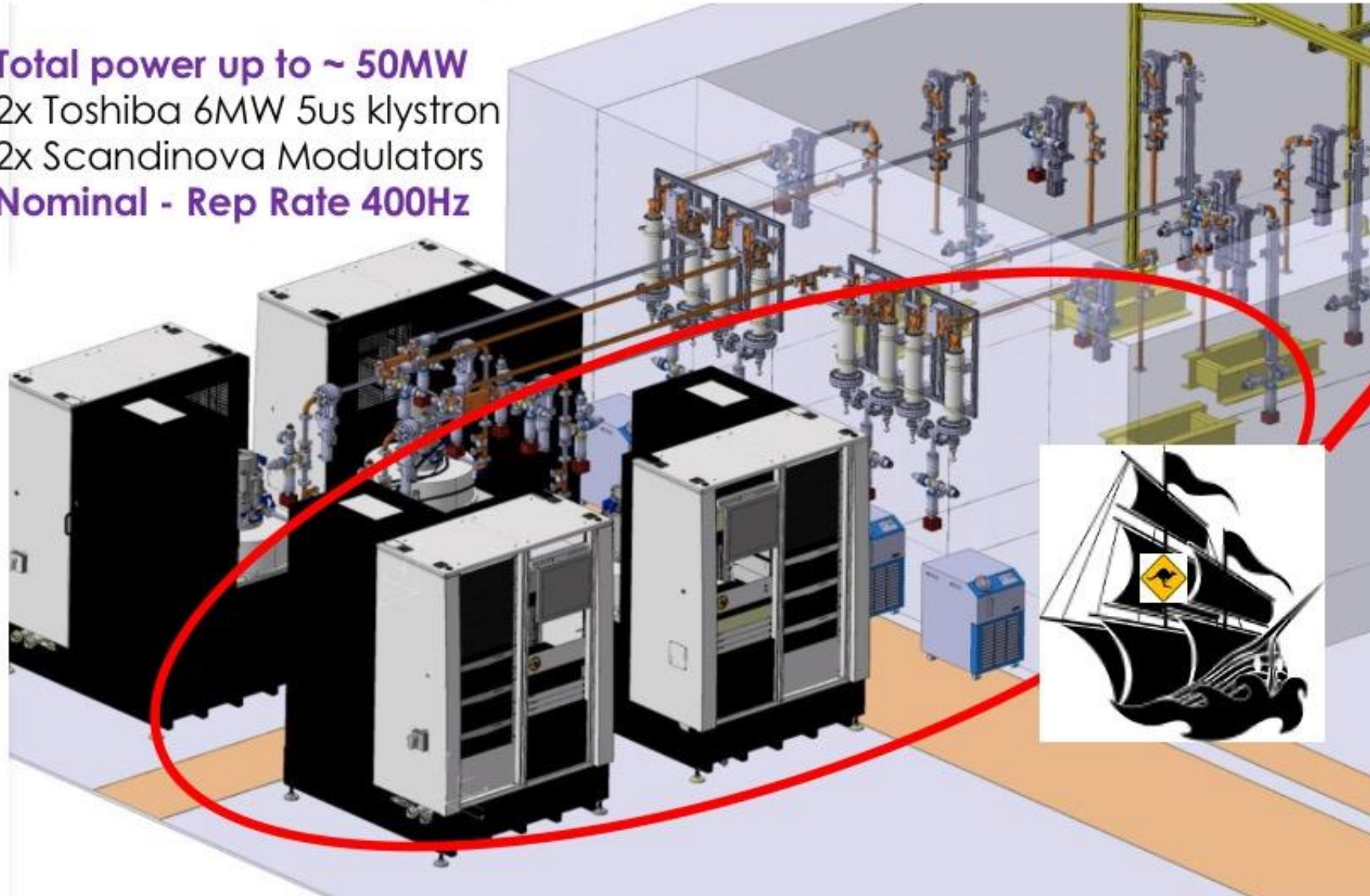
**Hannah Norman (start Oct 2020 Manchester)**

**Elodie Higgins (Masters student):**

Beamline characterization and optimization for FFA test beamline

# XBox3 system => ½ is coming to Melbourne

Total power up to ~ 50MW  
2x Toshiba 6MW 5us klystron  
2x Scandinova Modulators  
Nominal - Rep Rate 400Hz



Seven tons of high power RF network is already packed.



40 feet container for a value of about 6M\$ will arrive in Melbourne the 18<sup>th</sup> November

It's on it's way...

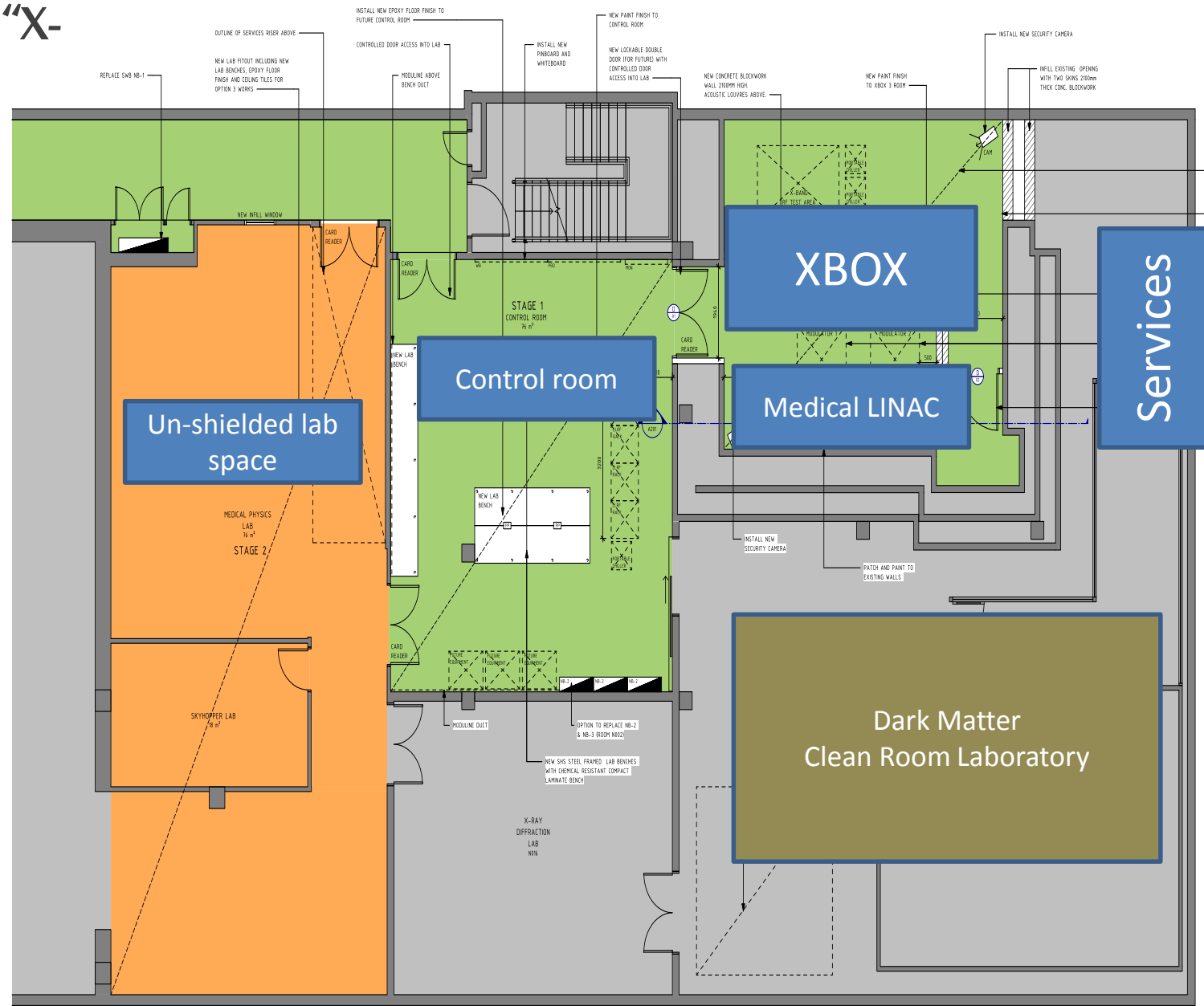
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# Basement Lab: The "X-Lab"

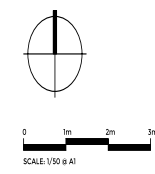


Pelletron & 1-4 MeV proton (beamline test area)



Bunker used to house a 35 MeV betatron

- LEGEND**
- EXISTING TO REMAIN
  - AREA OF WORKS - STAGE 1
  - AREA OF WORKS - STAGE 2
  - PROPOSED EQUIPMENT
  - POWER POLE ABOVE BENCH
  - INTERLOCKED DOORS
  - MODULE DUCT



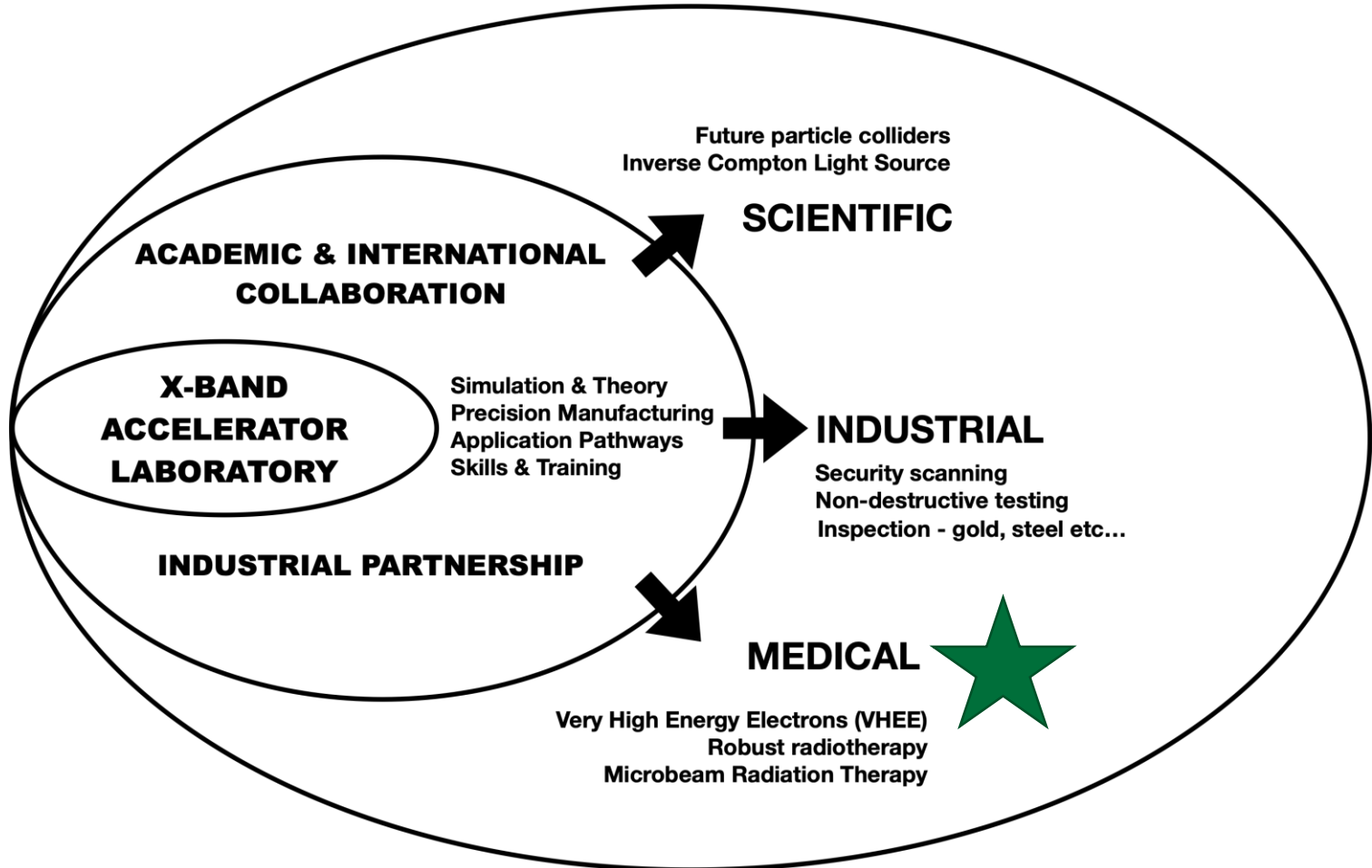
**PARTICLE ACCELERATOR**

THE UNIVERSITY OF MELBOURNE - BLD 192

*Melbourne will host the first high-frequency high-gradient accelerator lab in the Southern Hemisphere*



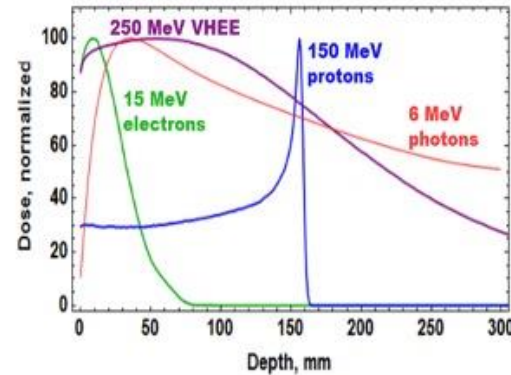
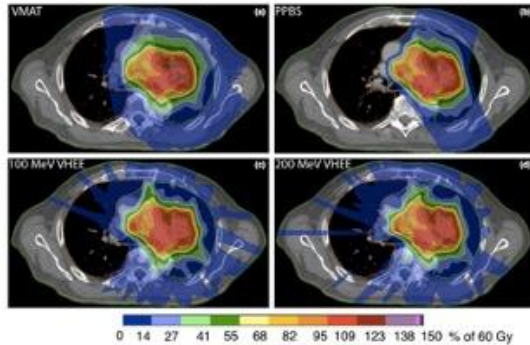
# Developing the accelerator ecosystem in Australia



Which applications will we focus on?

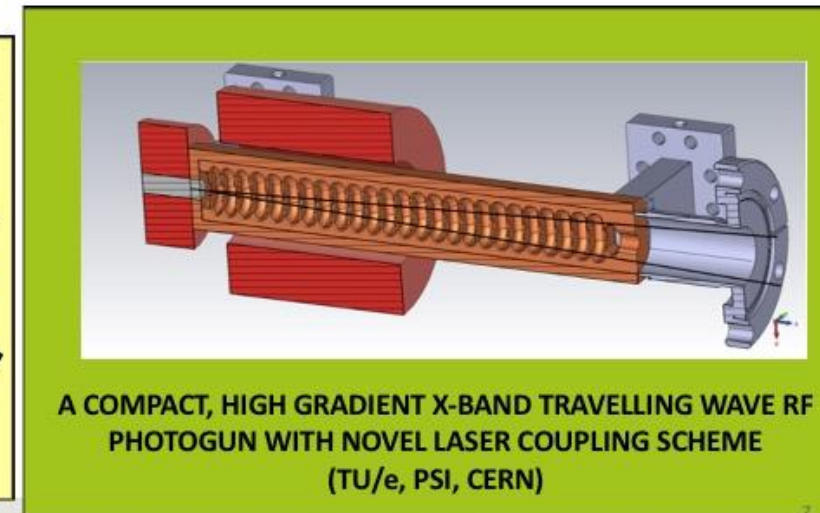
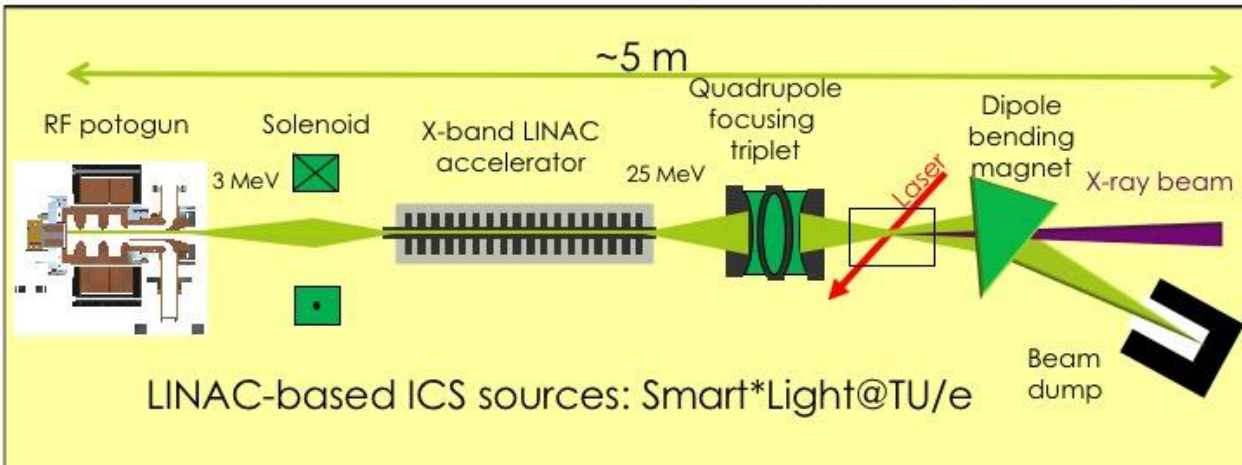
## X-band for Industrial and medical technologies

Very High Energy Electron (VHEE) therapy to complement existing X-ray, proton, and ion therapy. Use 250 MeV electron beam to treat tumors.



Dose profiles for various particle beams in water (beam widths  $r = 0.5$  cm)

### Ultraprecision machining



+ Low energy security scanning systems



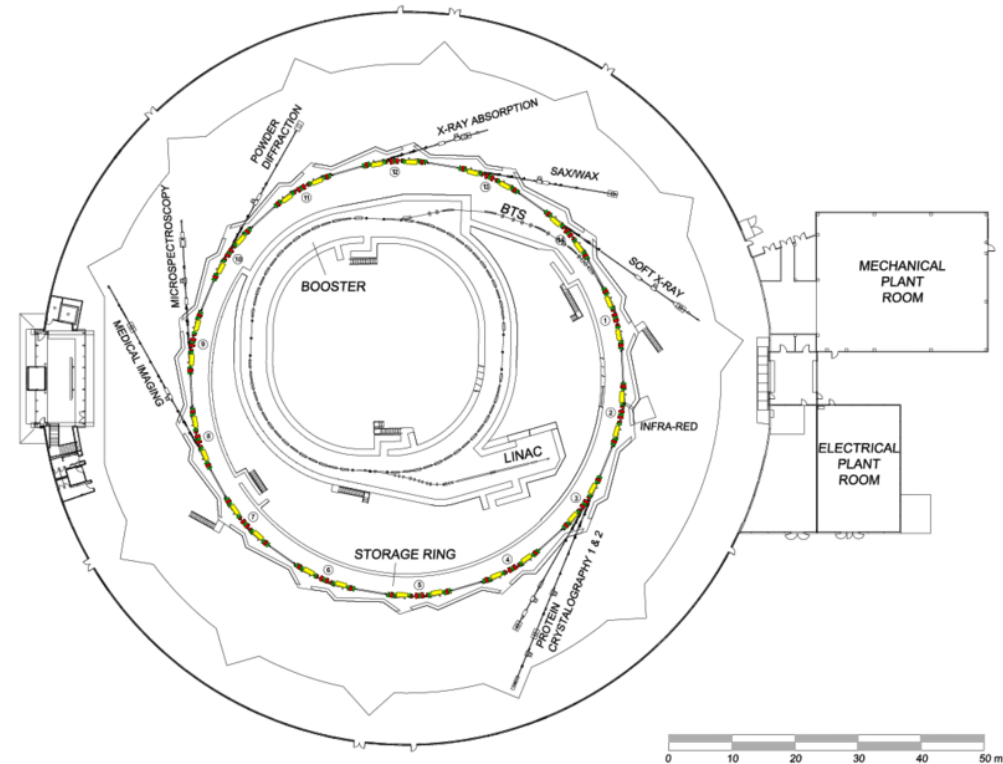
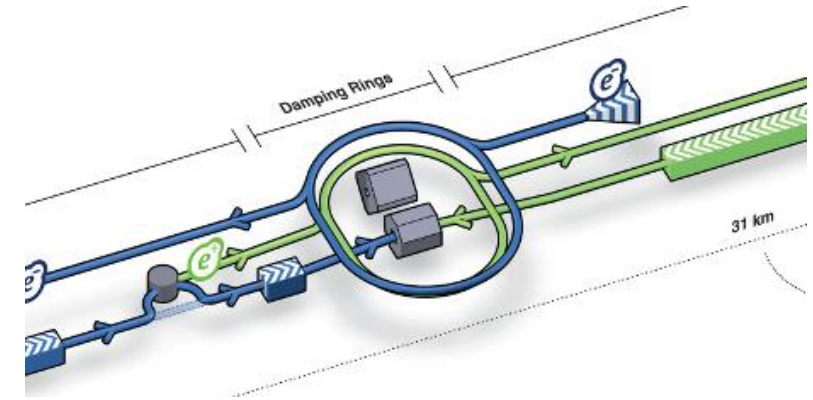
# Australian Synchrotron Research Areas

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- Optimisation and applying Machine Learning to operations
- Beam Coupling control
- Diagnostics development 'Real Time' beam optics measurements
- Compact Compton backscatter light source
- International Collaborations:
  - CompactLight - Undulator simulation and Beam buncher design
  - XBPM optimisation with LNLS and Soleil
  - X-LAB collaboration

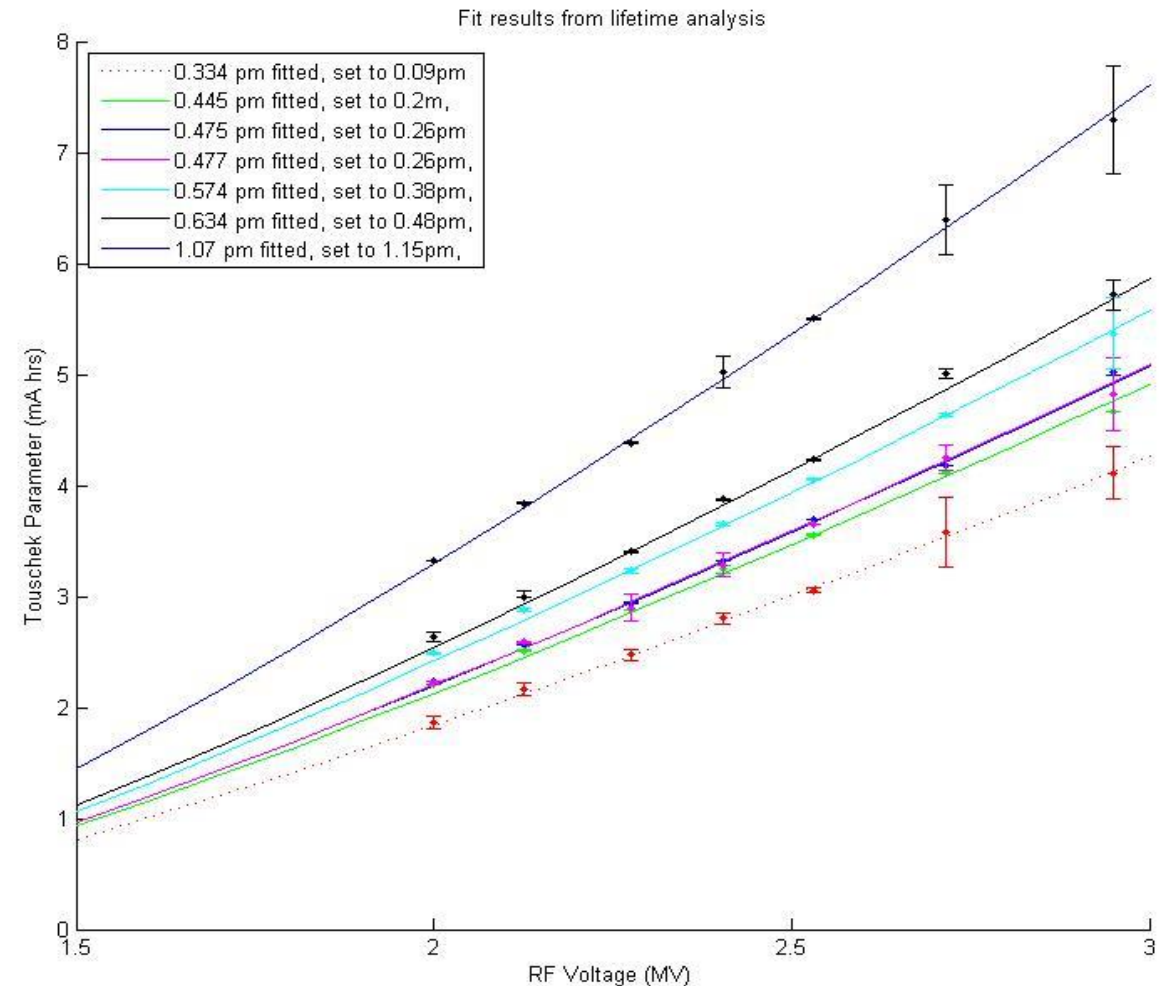
# Light Sources as a testing ground

- Light sources excel at beam stability and precision. Lessons learned at them can be applied to the collider community.
- Physicists at light sources often have the time and ability to test beam dynamics theories and hardware on an operating machine
- Light Sources are very similar to damping rings. Can demonstrate techniques needed for future accelerators.



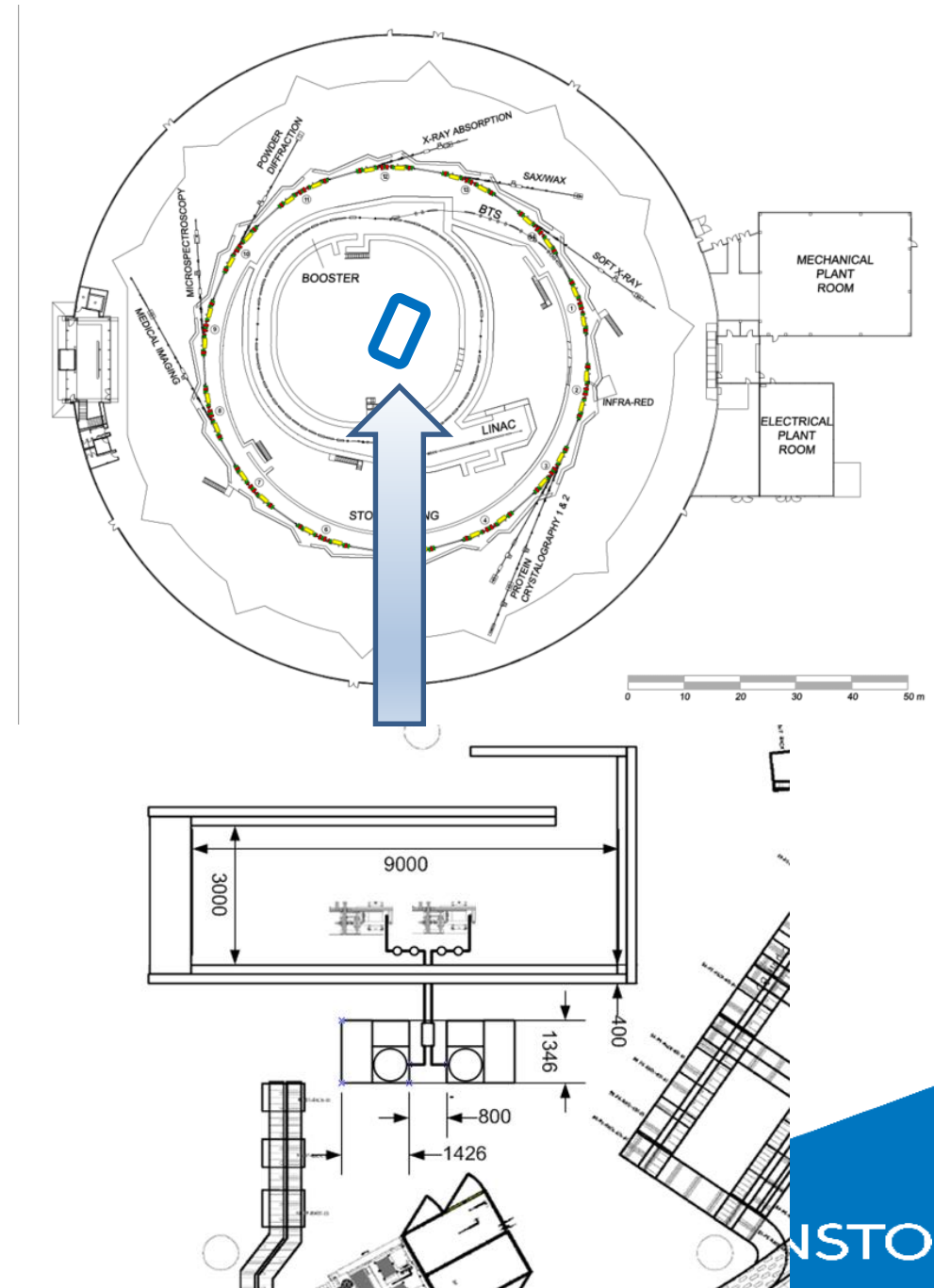
# Towards the Quantum Limit

- Demonstration of ultra-low vertical emittance important for future colliders.
- Employed a model based minimization technique, beam based magnet alignment and indirect measurements to achieve 1.3  $\mu\text{m}$  Vertical emittance – Phys. Rev. ST Accel. Beams 14, 012804 (2011)
- Since then, we have refined the technique and come very close to the Quantum limit
- Lessons learned in beam control have translated to better stability of AS beam



# Accelerator Test Facility at ANSTO

- ANSTO is developing an on site accelerator test infrastructure for the later stages of development into a Compton Source
- Will provide a 'Hands-on' lab that will enable substantial accelerator R&D without being tied to the needs of the Light source.
- Aiming to work in parallel with X-LAB lab to progress towards a Compton source, but will be a flexible facility.

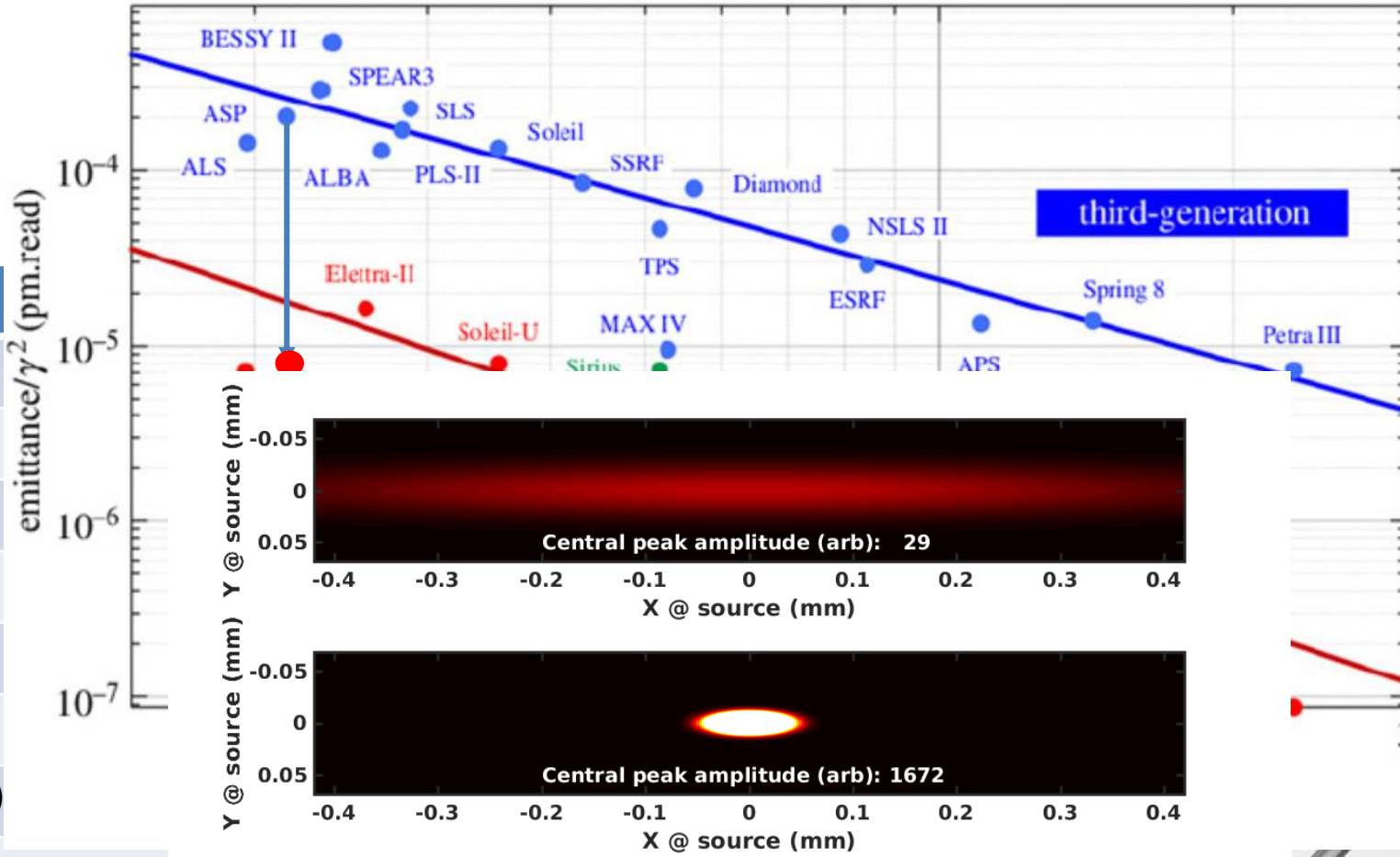


# New Lattice design – 4RA with reverse bends

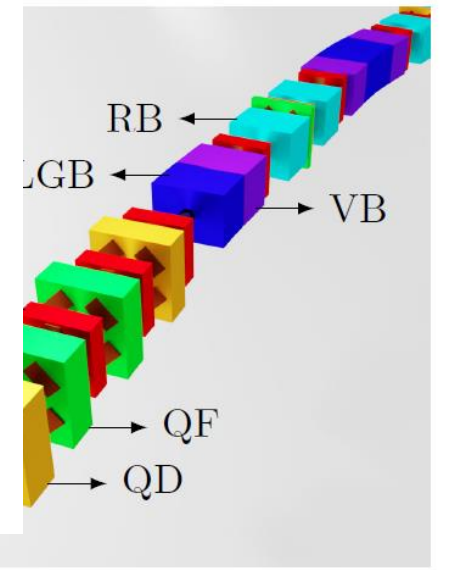
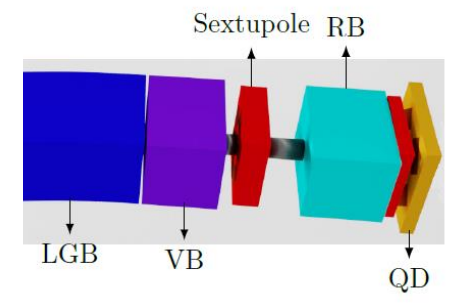
Design follows well as gradient

## Parameter

- Hor. Emittance (nm.rad)
- E Loss Per Turn (KeV)
- Energy Spread (%)
- Bunch Length [ps]
- Touscheck Lifetime (hrs)
- Coupling (%)
- Dipole Critical Energy (KeV)



Straight $\sigma_x$ [ $\mu\text{m}$ ]	322.75	19.115
Straight $\sigma_y$ [ $\mu\text{m}$ ]	17.464	5.317
Straight Length (m)	4.5	3.0



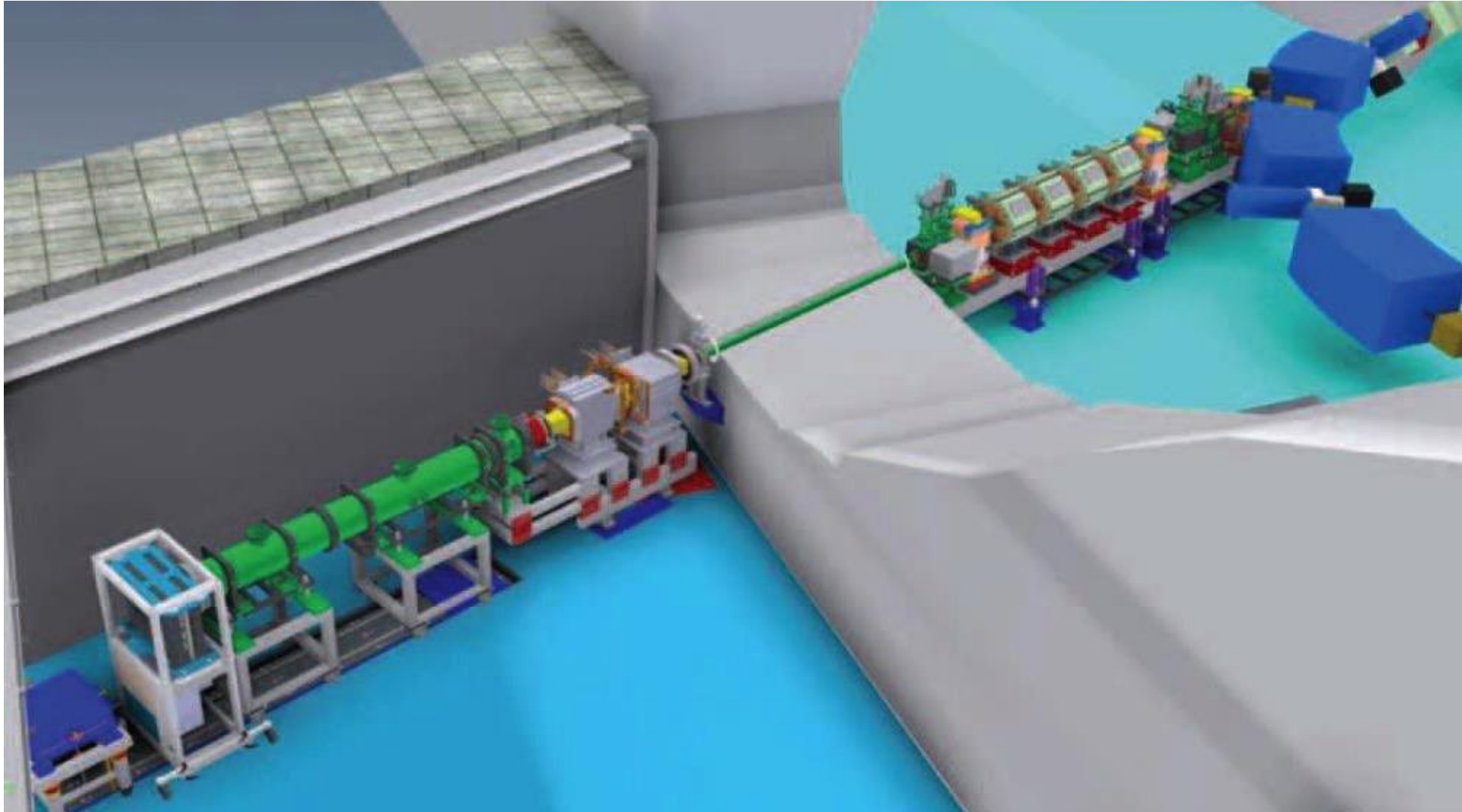
# Status of Hadron therapy

## Proposed network of facilities in Australia

Name	Proposed Location	Type of Centre
Australian Bragg Centre for Proton Treatment and Research	Adelaide SA	Proton
Construction commenced! Completion due 2023, patients 2025		
National Particle Treatment and Research Centre (NPTRC)	Sydney NSW	Carbon, proton, other ions
Queensland Proton Therapy and Research Centre (QPTRC)	Brisbane QLD	Proton
Victorian Proton Beam Therapy Centre	Melbourne Vic	Proton



# Flexible experimental room/beamline



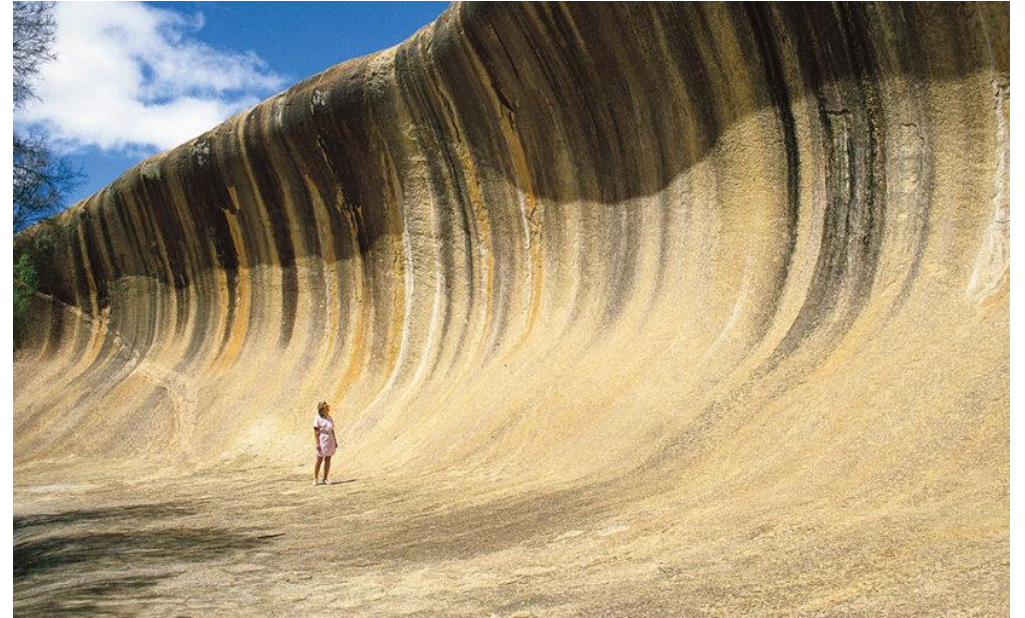
CNAO  
2016

# Capabilities for EIC



# Capability for Australia to Contribute to EIC

- Accelerator 'Ecosystem' in Australia is currently in its infancy, but we are planning to grow it. Limited capability for hardware contribution,
- Most current expertise is in high energy electron machine design and operation so probably natural to concentrate on that part of EIC.
- Immediate possibility is to contribute to design. Possible testing of prototype hardware on our infrastructure.



Early Australian Particle Accelerator